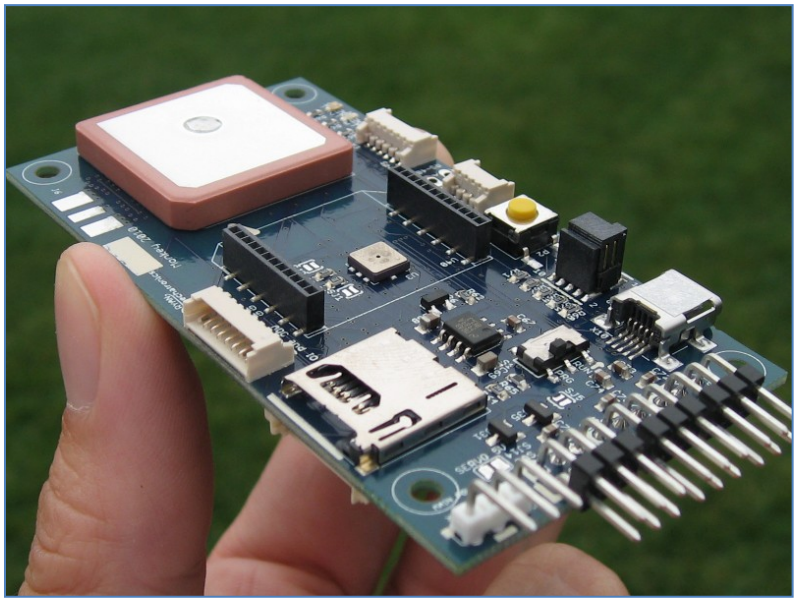
Monkey
User Manual



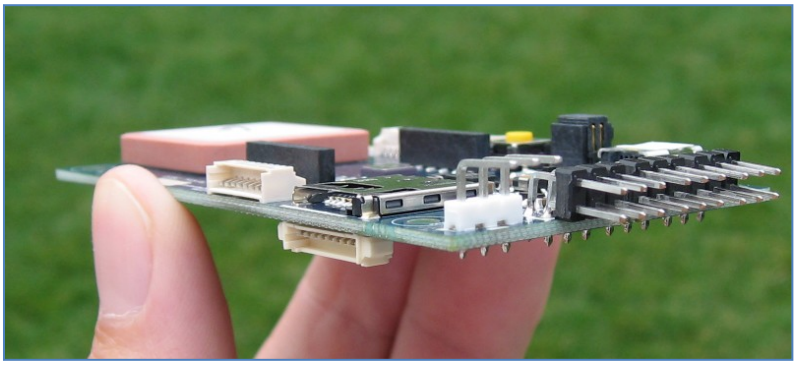


Table of Contents

Contents

1. Introduction 3
   1.1 Limitations 4
      1.1.1 Rate limits 4
      1.1.2 Acceleration limits 4
      1.1.3 Magnetic field limits 4
      1.1.4 GPS 4
      1.1.5 Precautions and User Responsibility 5
   1.2 Theory of Operation 5
      1.2.1 Startup Conditions 5
2. Specifications and Characteristics 7
   2.1 Performance Specifications – CPU 7
   2.2 Performance Specifications – Global Positioning Receiver 7
   2.3 Electrical Characteristics – Monkey 7
   2.4 Absolute Maximum Ratings 8
   2.5 Mechanical and Pin Assignments 9
      2.5.1 Dimensions 9
      2.5.2 Coordinate System and Orientation 9
      2.5.3 Pin Assignments 9
      2.5.4 Graphical Location of Connectors 15
3. Schematic Details 19
   3.1 Main ARM Processor 19
   3.2 Power Input 20
   3.3 Servo Output 20
   3.4 GPS Power and Antenna 21
   3.5 Reprogramming 22
   3.6 USB 22
   3.7 LEDs 23
   3.8 Barometric Pressure Sensor 23
   3.9 ADC and GPIO 24
   3.10 Communication ports 24
   3.11 Input Capture port 25
   3.12 User I2C and SPI 25
4. Hardware Integration 26
   4.1 Power 26
      4.1.1 Input Power 26
   4.2 GPS Antenna Options 26
5. Software Interface 28
   5.1 Recommended tools 28
   5.2 Firmware Upload Procedure 28
6. Appendix A – Reprogramming Example 29

Release Notes

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Subtitle	Monkey User Manual		
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1. Introduction

The Monkey platform provides a high performance basis for mechatronic system control. Originally designed for autonomous vehicle control, the platform can also be used for advanced data logging, industrial control, motion control or other mechatronic applications.

The Monkey 2010 platform is an enhanced version of prior Monkey circuit assemblies. The Monkey 2010 boards include:

- Powerful base CPU - Cortex M3 (ARM7) LPC 1768 Host Controller
    - Cortex SWD interface (tested with Rowley Crossworks)
    - Hardware based serial boot loader for easy loading of new software
- High performance U-Blox NEO-5 GPS Module
    - Active on board antenna for increased sensitivity and jamming reduction
- RS-485 driver on board for spare port
- Barometric pressure sensor
- Spare analog and digital I/O ports
- Six (6) Isolated and dedicated PWM servo outputs
- Four (4) input capture port connector
- Micro SD Card
- USB power and interface
- Three status LED's (red, green, blue)
- Interfaces with CHIMU module for attitude estimates and sensor inputs via SPI or UART

Monkey has an excellent GPS module on board (U-Blox series) with both on board and off board antenna capability. The off board antenna capability is important if the unit is used in conditions where the on board antenna will be blocked by enclosures or other jamming.

Monkey does not have on board inertial measurement sensors, but is intended to work with the CHIMU AHRS which includes:

- 3 axis rate sensors to measure angular rate
- 3 axis accelerometers to measure linear acceleration
- 3 axis magnetometer to measure magnetic flux (typically used for compass type heading derivation)

The combination of all these capabilities with the on board ARM processing power allows a full attitude heading reference system (AHRS) with GPS position, velocity and time updates all in one tiny package.

Application areas include, but are not limited to:

- UAVs (AUVs, UAS, etc)
- Robotics
- Education
- Rocket science

1.1 Limitations

The unit, like any device designed to utilize GPS and IMU / AHRS data, can be pushed beyond the limits of its ability to sense any of the measurements it needs to operate correctly. The following list includes results that are known to occur if operation (when using the CHIMU module) exceeds the limits listed later in this document.

1.1.1 Rate limits

Saturation of maximum rate in any axis for any amount of time will result in an incorrect attitude estimate. The longer the saturation duration, the more error will be present in the attitude determination. A good attitude estimator shall recover once saturation has stopped and the internal filter has time to reconverge on the correct solution.

Please note: The Monkey does NOT ship with an attitude estimator set of code, but it has the processing and code memory to host an estimator of the customers design and use raw output from the CHIMU module.

1.1.2 Acceleration limits

Excessive acceleration can include acceleration above the rated levels in continuous application (static / low frequency g's), more elusive vibration (sinusoidal / random) or shock (impulse / random) events that may not show full saturation of the accelerometers in data output, but have affected the sensors internally and corrupted the values. Continued acceleration above the limits or excessive vibration / shock events can corrupt the output acceleration.

1.1.3 Magnetic field limits

Magnetometers are sensitive to hard and soft iron effects, as well as induced magnetic fields from high current. Saturation of the local magnetic field is easily identified, but lower level influence on the sensor can result in pervasive errors as well. Calibration of the unit in the final configuration will help prevent errors introduced by hard iron in the local area. However, induced magnetic fields from high current devices or high power RF circuitry can result in operational errors. After a proper calibration, no axis should exceed a +/- 1 gauss value.

1.1.4 GPS

GPS is a phenomenal technology allowing location of your position on the planet Earth within about a 15 foot (5 meter) accuracy using a module the size of your thumb!

GPS is subject to many possible interference sources, including anything in the GPS frequency band (including harmonics of lower frequencies from digital systems) and other jamming sources, like foliage or direct blockage of the antenna.

This manual cannot begin to educate the user on limits of GPS technology, but we recommend both Wikipedia and the support area on the U-blox (www.ublox.com) website for more information.

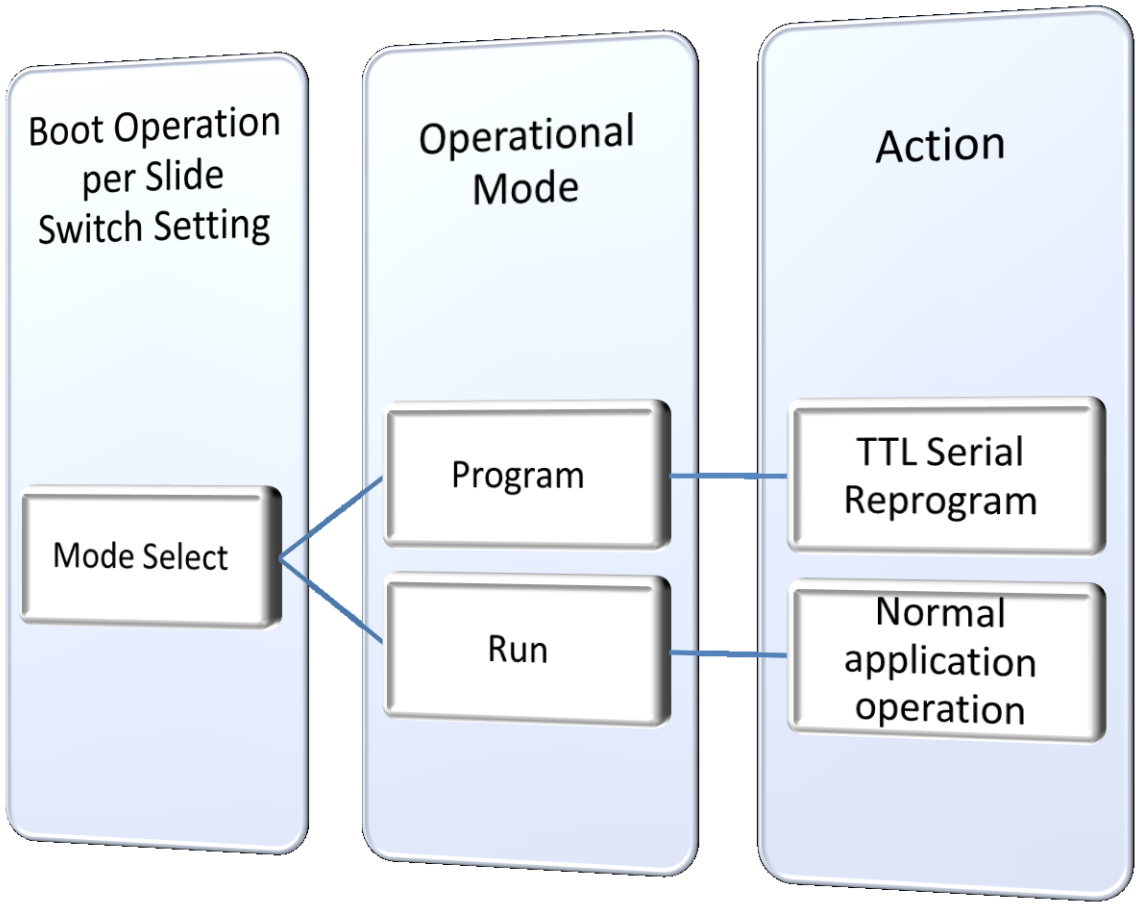
1.1.5 Precautions and User Responsibility

The Monkey is an open electrical device with no case. It has no on board protection from short circuits or accidental electrical damage. No system is fool proof, and all correct use and planning for events in case of failure are the responsibility of the user.

Ryan Mechatronics cannot be held responsible for accidental or intentional damage caused by this unit either directly or indirectly.

1.2 Theory of Operation

The Monkey platform is an excellent prototyping system for users that want or need the power of an ARM Cortex core. User application code can be run on the core. However, the design makes it easy for the on-board ARM processor to be reprogrammed by using on-board firmware upload capability. This allows new Intel HEX formatted code to be uploaded using the serial port. A top level view of the usage modes is shown in the following figure.



1.2.1 Startup Conditions

The startup condition of the S4 switch on the Monkey dictates what mode the system enters when reset or power is applied.

On Board ARM CPU running user code: For operation in standalone mode, user must have code loaded and running on the processor. In this case, switch **S4** would be in the "RUN" position.

Reprogramming: In order to reprogram the board, switch **S4** would be set to "PRG" before power is applied. When power is applied in this state, the on board boot loader of the ARM is active. Programming steps in this state can be found in Appendix A – Reprogramming Example .

2. Specifications and Characteristics

Presented in this section are the sensor and system specifications for the Monkey. All parameters specified are @ VDD = 3.3 V and Ta = 25°C.

2.1 Performance Specifications – CPU

The performance specifications of the LPC1768 core processor are too numerous and detailed to reproduce here. Please see the following link for specific information on the LPC1768:

http://www.nxp.com/documents/data_sheet/LPC1769_68_67_66_65_64_63.pdf

2.2 Performance Specifications – Global Positioning Receiver

Characteristics	Conditions	Min	Typical	Max	Units
Position, Velocity and Time					
Time to First Fix	Cold Start Warm Start Hot Start		29 29 <1		s
Horizontal position accuracy	Without SBAS SBAS		<2.5 <2.0		m
Max Navigation Update Rate	Message dependent	2	2	4	Hz
Velocity accuracy			0.1		m/s
External antenna power supply	Center feed on external antenna connection		3.3		*V*

- Specifications are subject to change at any time without notice

2.3 Electrical Characteristics – Monkey

The following electrical characteristics relate to the Monkey board with a CHIMU module attached. Current draw is heavily dependent on code operation.

Characteristics	Conditions	Min	Typical	Max	Units
Power					
5V Input Supply Voltage Range	V_{dd} Referenced to GND	4.6	5.0	5.2	V
Current	Average, measured at 5V • 48 Mhz core operation • GPS in signal acquisition (track results in lower current) • CHIMU running • SD card logging 10 Hz data at 1 Hz intervals • PWM active	110	150	180	mA

- Specifications are subject to change at any time without notice

2.4 Absolute Maximum Ratings

Parameter	Rating
Acceleration (any axis, 0.5 ms) Unpowered	2000g
V_{dd}	-0.3V to +7V
Output Short-Circuit Duration (Any Pin to Common)	TBD
Operating Temperature Range	-30°C to +85°C
Storage Temperature Range	-40°C to +125°C

- Specifications are subject to change at any time without notice

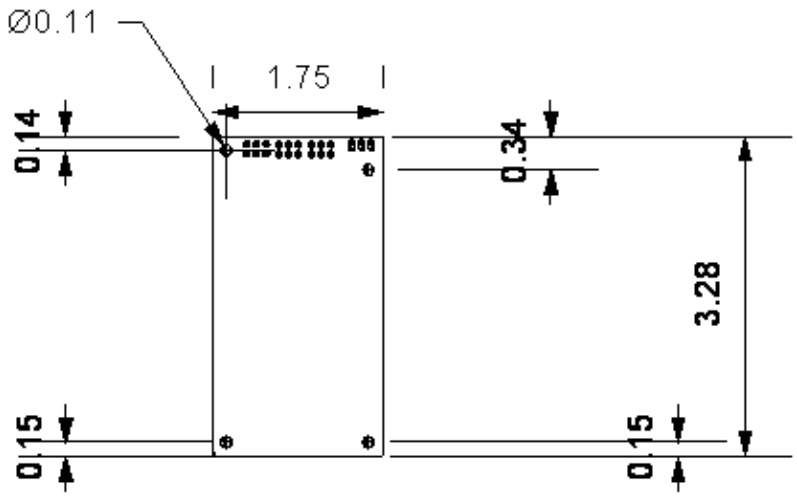
Stresses above those listed under the Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at or near these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect device reliability.

Drops onto hard surfaces can cause shocks of greater than 2000 *g* and can exceed the absolute maximum rating of the device. Exercise care during handling to avoid damage.

2.5 Mechanical and Pin Assignments

2.5.1 Dimensions

Dimensions and outline for the unit are shown below. All units are in inches.



Mounting holes are designed to accommodate standard 4-40 screw sizes.

2.5.2 Coordinate System and Orientation

The Monkey board does not have a coordinate system of its own, but when used with the CHIMU attitude estimator, it follows a standard (X/Y/Z) coordinate system as shown, where +X is out the "nose" of the Monkey board, +Y is to the right, and +Z points down.

2.5.3 Pin Assignments

Shown in this section are names for each of the signals on the Monkey connectors, along with warnings / information as applicable.

Table 1 – User Connector Overview

Connector ID	Connector Name / Function	Description
SV4	Main Power	Primary +5V power input to the system and input for battery voltage monitoring **WARNING**: This power pin is common with USB 5V power and there is limited protection. Overvoltage or shorting this pin while it is connected to your computer can damage your computer. Use either 5V power input, or USB power input. Do not have multiple power sources connected.
SV5	Servo Output 1-2	PWM output (isolated) for servo channels 1 and 2
SV6	Servo Output 3-4	PWM output (isolated) for servo channels 3 and 4
SV7	Servo Output 5-6	PWM output (isolated) for servo channels 5 and 6
SV8	RS-485	RS-485 output (optional, controlled by software)
X1	ADC/GPIO	Four (4) ADC inputs (2 buffered and 2 un-buffered) and two (2) GPIO lines
X2	User I2C and SPI	User dedicated I2C bus SPI lines (shared by SD card)
X3	Spare serial and CHIMU serial ports	Two (2) 3.3V level serial ports. Spare port is routed to RS-485 output if selected by software. CHIMU serial port available for output if CHIMU configured for SPI com only
X10	USB	USB communication to ARM (if supported in software) Used for 5V external power. **WARNING**: This power pin is common with Primary 5V power and there is limited protection. Overvoltage or shorting this pin while it is connected to your computer can damage your computer. Use either 5V power input, or USB power input. Do not have multiple power sources connected.
X16	Main Com	3.3V level serial port (primary com port to / from Monkey)
X19	Input Capture	Four (4) input capture ports for servo PWM input capture. Can also be reconfigured for added GPIO
J1	SWD	Serial Wire Debug interface to ARM processor
U40	CHIMU	Allows plug in of CHIMU attitude estimator module

Table 2 - Pin Assignments SV4 – Primary Power

Pin #	Pin Label	Pin Name	I/O	Description
1	X	Vbat	I	ADC input to ARM intended for battery voltage monitoring. 270 ohm limiting resistor in line, but input voltage must be scaled off board (i.e. Power Node). **WARNING**! This is NOT to be tied directly to a battery. Do not exceed 3.3V input or damage will occur to unit.
2	5V	5V	N/A	5V external power. **WARNING**: This power pin is common with USB 5V power and there is limited protection. Overvoltage or shorting this pin while it is connected to your computer can damage your computer. If using USB power, do not connect this pin to anything. Use either 5V power input, or USB power input. Do not have multiple power sources connected.
3	GND	Ground	N/A	System ground

Table 3 - Pin Assignments SV5 – Servo Output 1/2

Pin #	Pin Label	Pin Name	I/O	Description
1	1	Servo 1 Output	O	PWM output for Servo 1
2	-	Servo 2 Output	O	PWM output for Servo 2
3	-	Servo5V	Power	Servo 5V supply
4	-	Servo5V	Power	Servo 5V supply
5	-	GndServo	Ground	Servo Ground
6	6	GndServo	Ground	Servo Ground

Servo 5V and Servo Ground are isolated from main system and ground. This can be defeated by jumping SJ10 and SJ14.

Table 4 - Pin Assignments SV6 – Servo Output 3/4

Pin #	Pin Label	Pin Name	I/O	Description
1	1	Servo 3 Output	O	PWM output for Servo 3
2	-	Servo 4 Output	O	PWM output for Servo 4
3	-	Servo5V	Power	Servo 5V supply
4	-	Servo5V	Power	Servo 5V supply
5	-	GndServo	Ground	Servo Ground
6	6	GndServo	Ground	Servo Ground

Servo 5V and Servo Ground are isolated from main system and ground. This can be defeated by jumping SJ10 and SJ14.

Table 5 - Pin Assignments SV7 – Servo Output 5/6

Pin #	Pin Label	Pin Name	I/O	Description
1	1	Servo 5 Output	O	PWM output for Servo 5
2	-	Servo 6 Output	O	PWM output for Servo 6
3	-	Servo5V	Power	Servo 5V supply
4	-	Servo5V	Power	Servo 5V supply
5	-	GndServo	Ground	Servo Ground
6	6	GndServo	Ground	Servo Ground

Servo 5V and Servo Ground are isolated from main system and ground. This can be defeated by jumping SJ10 and SJ14.

Table 6 - Pin Assignments SV8 – RS-485

Pin #	Pin Label	Pin Name	I/O	Description
1	B	RS_485B	I/O	B line for RS-485 (differential with A)
2	A	RS_485A	I/O	A line for RS-485 (differential with B)
3	GND	GND	Ground	System ground

Table 7 - Pin Assignments X1 – ADC/GPIO

Pin #	Pin Label	Pin Name	I/O	Description
1	GP1	GPIO1	I/O	270 ohm current limited I/O to ARM
2	GP0	GPIO0	I/O	270 ohm current limited I/O to ARM
3	AD5	ADC5	ADC	Unbuffered ADC5 to ARM. Do not exceed 3.3V.
4	AD4	ADC4/VBUS	ADC	Unbuffered ADC4 to ARM. Do not exceed 3.3V. Alternate use required for USB com (future upgrade).
5	3.3V	3.3V	Power	3.3V output from on board LDO for use in powering external signal conditioning or sensors
6	G	GND	Ground	System ground
7	AD1	ADC1	ADC	Buffered ADC1 to ARM. Buffer is a passive resistor divider (5k on each leg) that cuts incoming voltage by a factor of 2. 5V input on this line reduced to 2.5V which is within 3.3V limit of ADC.
8	AD0	ADC0	ADC	Buffered ADC0 to ARM. Buffer is a passive resistor divider (5k on each leg) that cuts incoming voltage by a factor of 2. 5V input on this line reduced to 2.5V which is within 3.3V limit of ADC.

For ARM pins, typical use is shown but can be reconfigured. Please see the LPC1768 User Manual from NXP for other pin options.

Table 8 - Pin Assignments X2 – User I2C and SPI

Pin #	Pin Label	Pin Name	I/O	Description
1	-	SD_!CS_ALT	I/O	Chip select alternate
2	-	SD_MOSI0	I/0	MOSI0 to ARM
3	-	SD_MIOS0	I/O	MIOS0 to ARM
4	-	SD_!CS0	I/O	!CS to ARM
5	-	SD_CLK0	I/O	CLK0 to ARM
6	3.3V	3.3V	Power	3.3V output from on board LDO for use in powering external signal conditioning or sensors
7	G	GND	Ground	System ground
8	-	SCL1_USER	I2C	I2C SCL line to ARM. 1k pull-up to 3.3V on board
9	-	SDA1_USER	I2C	I2C SDA line to ARM. 1k pull-up to 3.3V on board

For ARM pins, typical use is shown but can be reconfigured. Please see the LPC1768 User Manual from NXP for other pin options.

Table 9 - Pin Assignments X3 – Spare Serial Communication

Pin #	Pin Label	Pin Name	I/O	Description
1	-	SP_TX	I/O	UART TX1 (3.3V level)
2	-	SP_RX	I/O	UART RX1 (3.3V level)
3	-	3.3V	Power	3.3V output from on board LDO for use in powering external signal conditioning or sensors
4	-	GND	Ground	System ground
5	-	CHIMU_RX	I/O	UART RX3 (3.3V level)
6	-	CHIMU_TX	I/O	UART TX3 (3.3V level)

For ARM pins, typical use is shown but can be reconfigured. Please see the LPC1768 User Manual from NXP for other pin options.

Table 10 - Pin Assignments X10 – USB

Pin #	Pin Label	Pin Name	I/O	Description
1-4	-	-	Mixed	Standard 4 pin USB connector, mini-B

Table 11 - Pin Assignments X16 – Main Serial Com

Pin #	Pin Label	Pin Name	I/O	Description
1	-	3.3V	Power	3.3V output from on board LDO
2	-	GND	Ground	System ground
3	-	COM_RX	I/O	UART RX0 (3.3V level)
4	-	COM_TX	I/O	UART TX0 (3.3V level)

For ARM pins, typical use is shown but can be reconfigured. Please see the LPC1768 User Manual from NXP for other pin options.

Table 12 - Pin Assignments X19 – Input Capture

Pin #	Pin Label	Pin Name	I/O	Description
1	-	CAP 1.1	I/O	Capture pin 1.1
2	-	CAP 1.0	I/O	Capture pin 1.0
3	-	CAP 0.1	I/O	Capture pin 0.1
4	-	CAP 0.0	I/O	Capture pin 0.0

For ARM pins, typical use is shown but can be reconfigured. Please see the LPC1768 User Manual from NXP for other pin options.

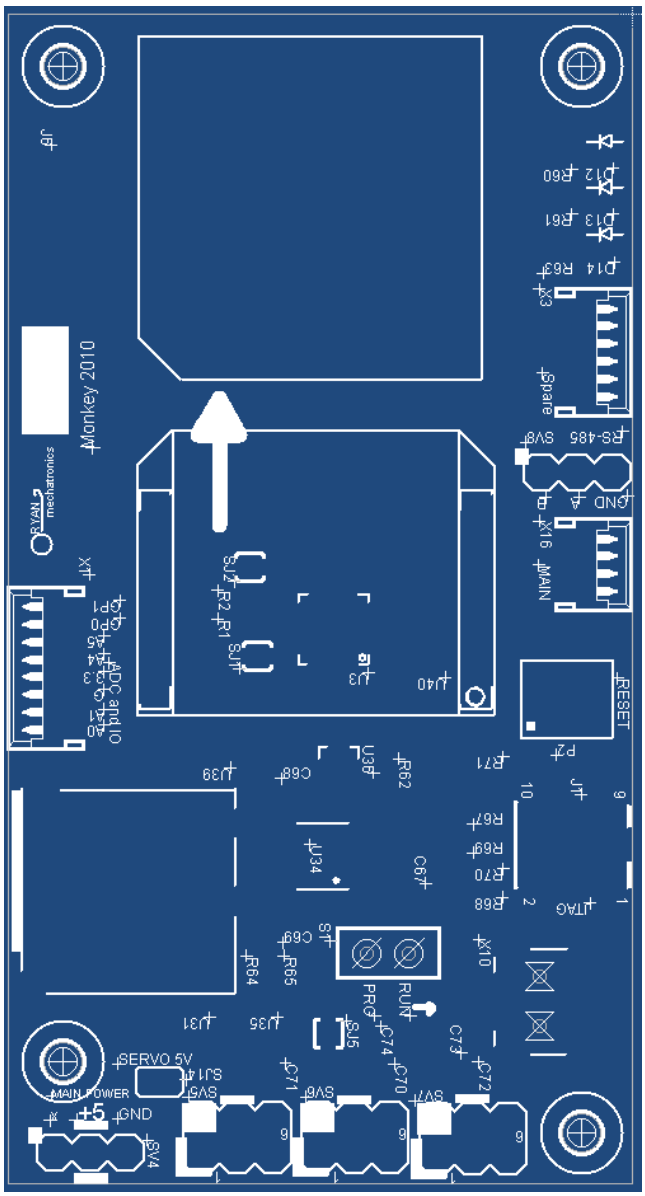
Table 13 - Pin Assignments J1 – Serial Wire Debug (SWD)

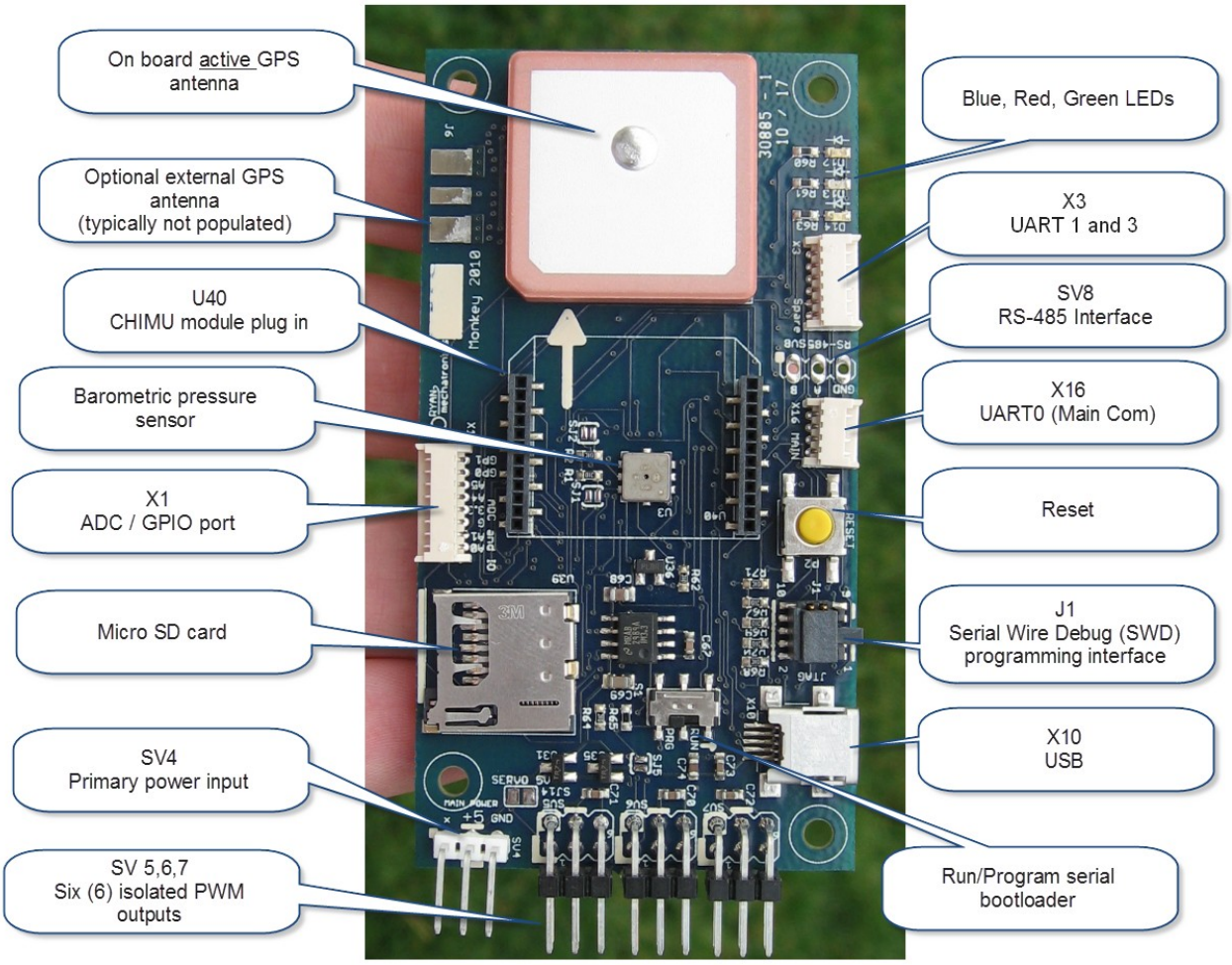
Pin #	Pin Label	Pin Name	I/O	Description
1	-	3.3V	Power	3.3V power
2	-	TMS/SWDIO	I/O	SWD standard
3	-	GND	Ground	System ground
4	-	TCK/SWCLK	I/O	SWD standard
5	-	GND	Ground	System ground
6	-	TDO/SWO	I/O	SWD standard
7	-	RTCK	I/O	SWD standard
8	-	TDI	I/O	SWD standard
9	-	GND	Ground	System ground
10	-	!RESET	I/O	SWD standard

2.5.4 Graphical Location of Connectors

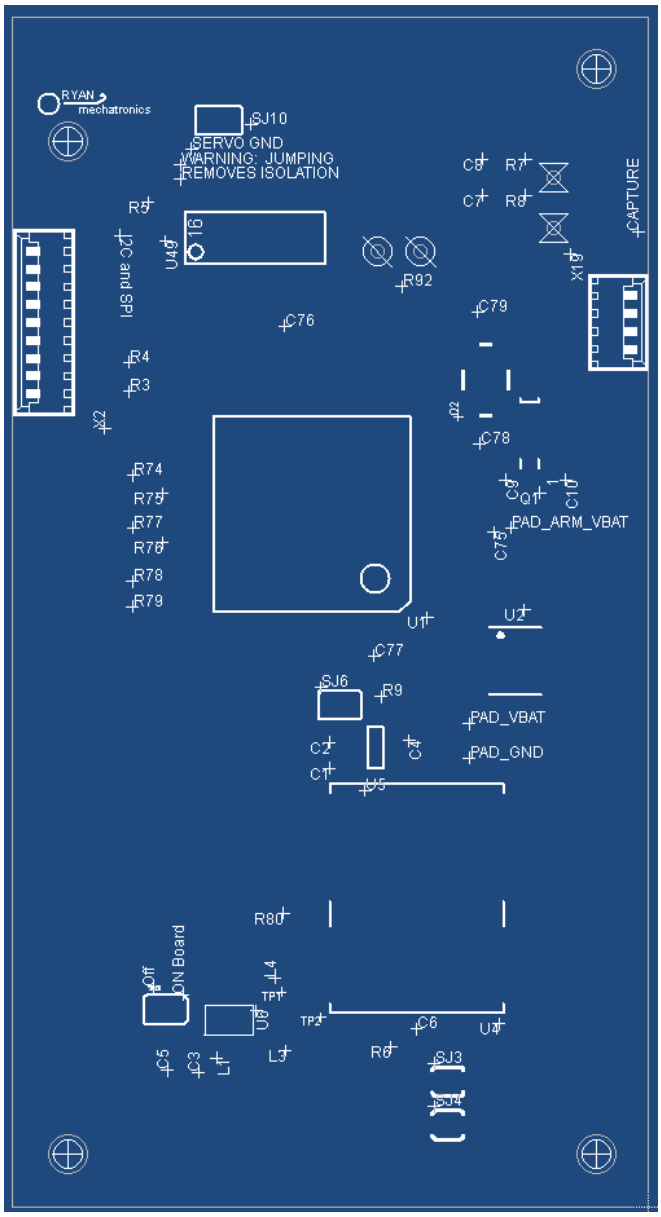
Reprinted here is the silkscreen for the Monkey board top and bottom artwork. Locations of all components and connectors can be found here.

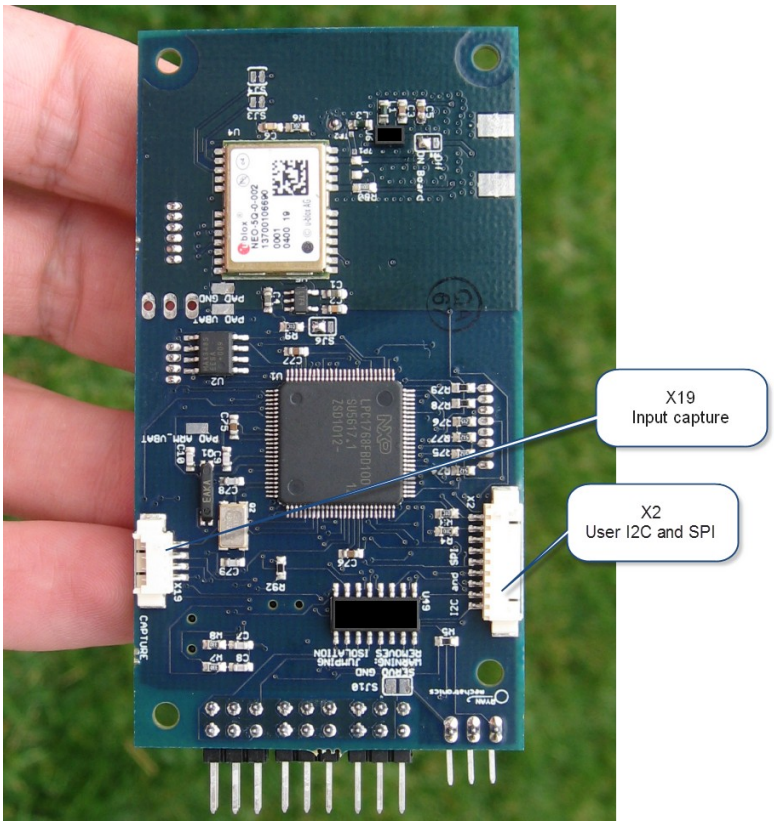
2.5.4.1 Top Side




On board active GPS antenna
Optional external GPS antenna (typically not populated)
U40 CHIMU module plug in
Barometric pressure sensor
X1 ADC / GPIO port
Micro SD card
SV4 Primary power input
SV 5,6,7 Six (6) isolated PWM outputs
Blue, Red, Green LEDs
X3 UART 1 and 3
SV8 RS-485 Interface
X16 UART0 (Main Com)
Reset
J1 Serial Wire Debug (SWD) programming interface
X10 USB
Run/Program serial bootloader

2.5.4.2 Bottom Side



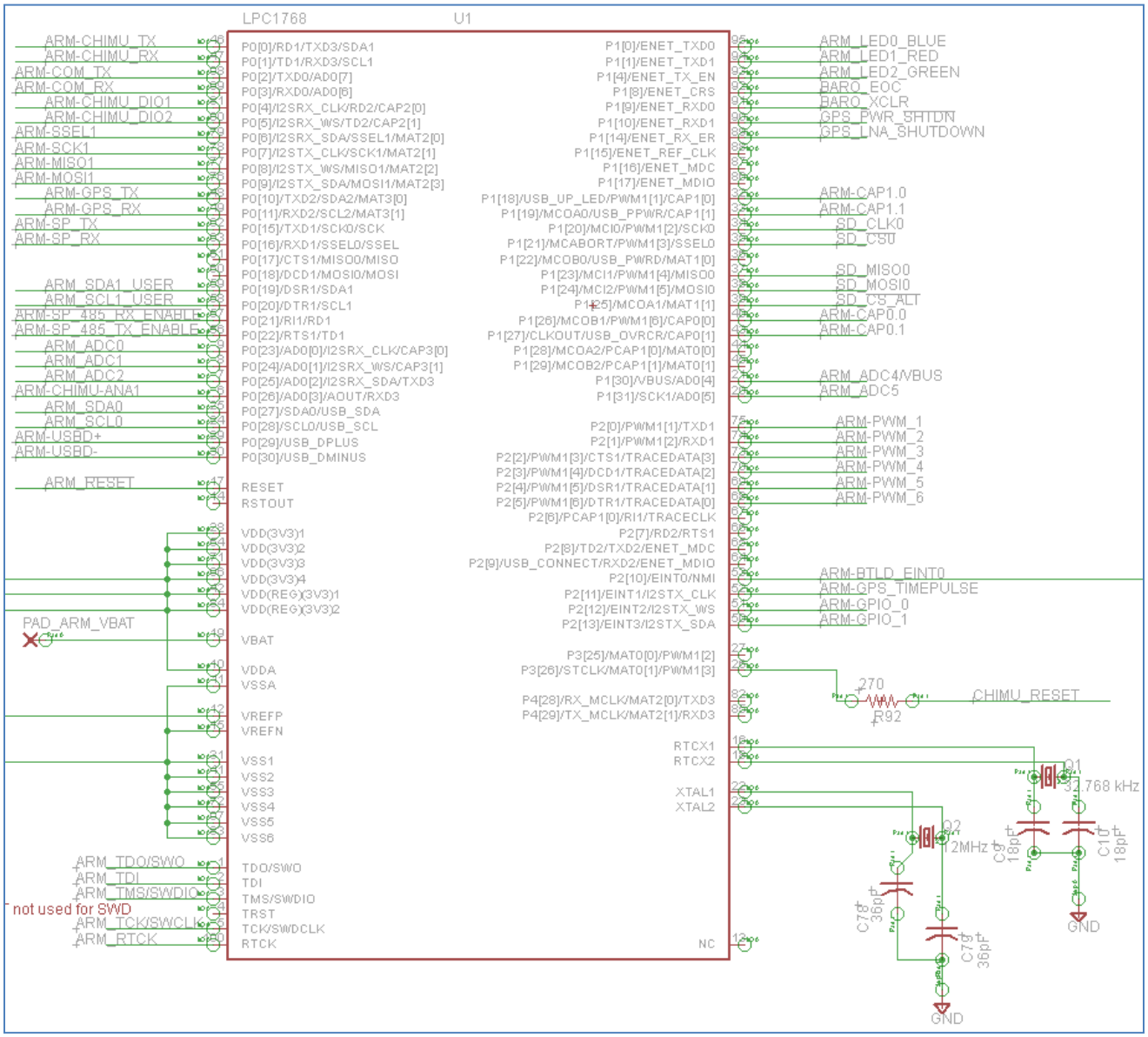

X19
Input capture
X2
User I2C and SPI

3. Schematic Details

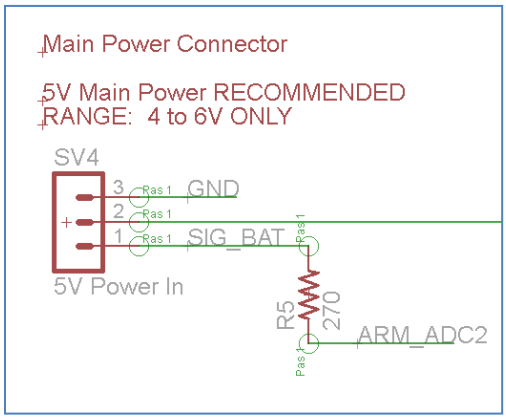
Presented in this section are schematic details required for users to correctly program the board for alternate applications.

3.1 Main ARM Processor

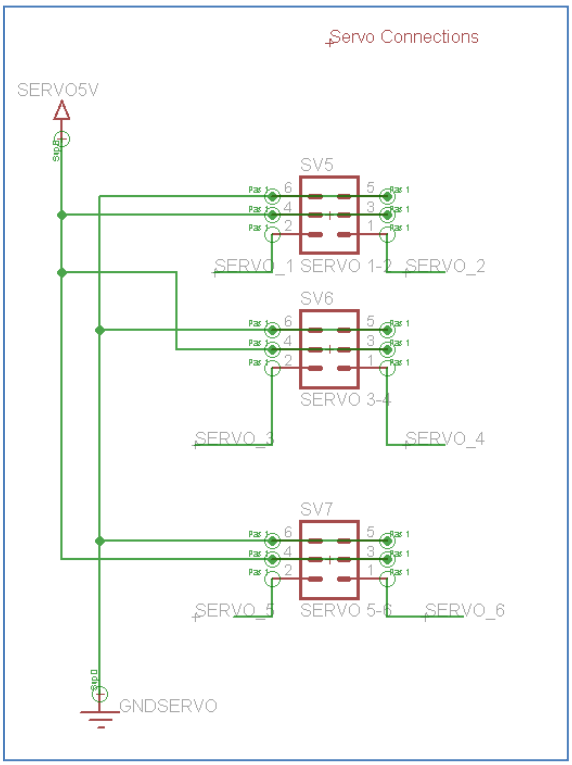
Pins for the ARM connection are shown below for reference.



3.2 Power Input

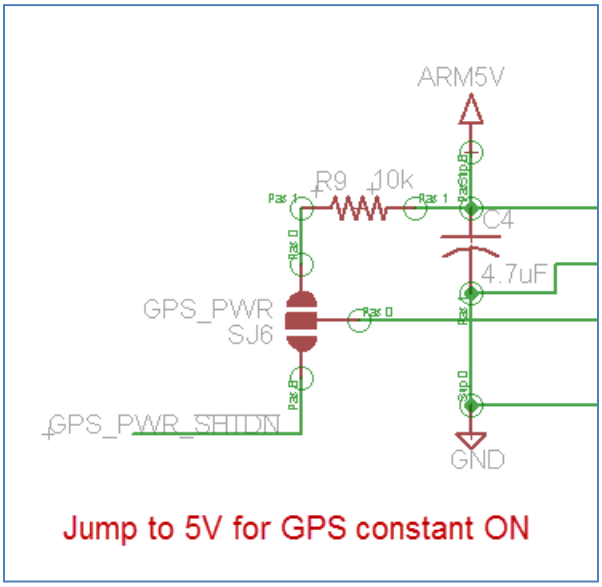


3.3 Servo Output

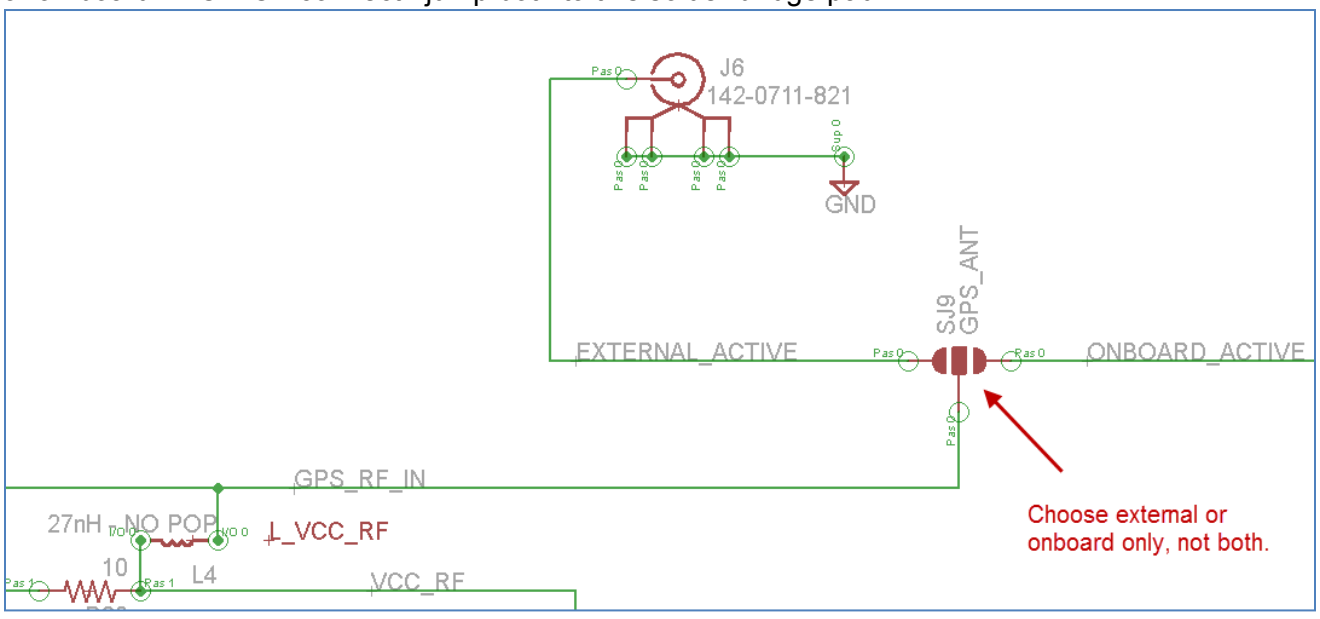


3.4 GPS Power and Antenna

For GPS power always on, jump SJ6 to R9 (this is default for shipping). If power to GPS needs to be shut off to conserve power, jump SJ6 to GPS_PWR_SHTDN and power control is dictated by ARM processor code.

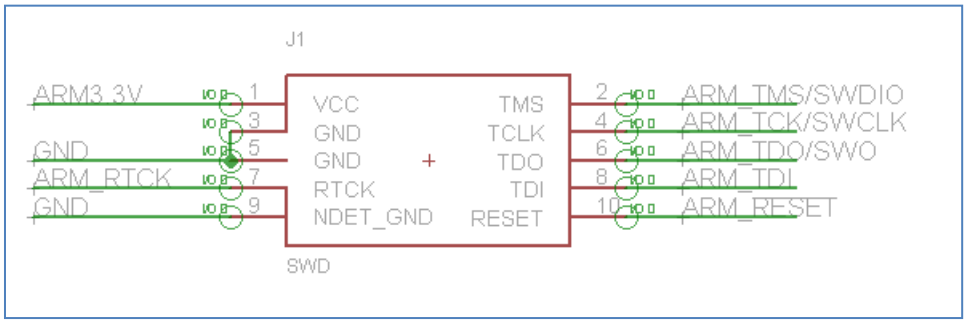


For onboard active antenna, L_VCC_RF is NO POP. For off board active antenna, L_VCC_RF inductor of 27nH should be installed (0603 pads). SJ9 must be selected correctly for either onboard or off board. DO NOT connect / jump both to this solder bridge pad.



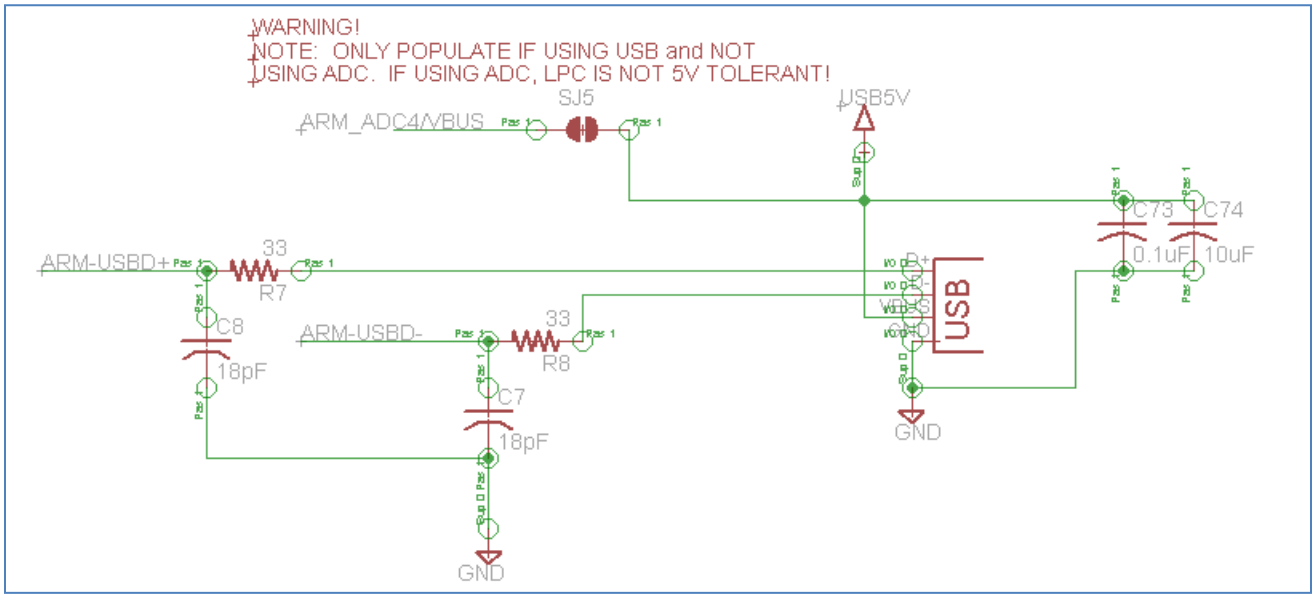
3.5 Reprogramming

SWD connector J1 is shown here.



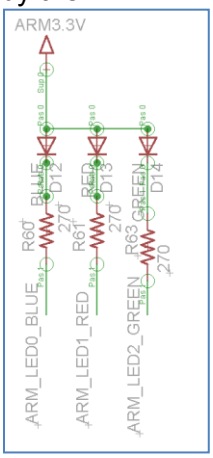
3.6 USB

USB communication is not part of the Monkey base code. However, Monkey can be powered from a USB connection for easy bench testing and future code will support USB communication.



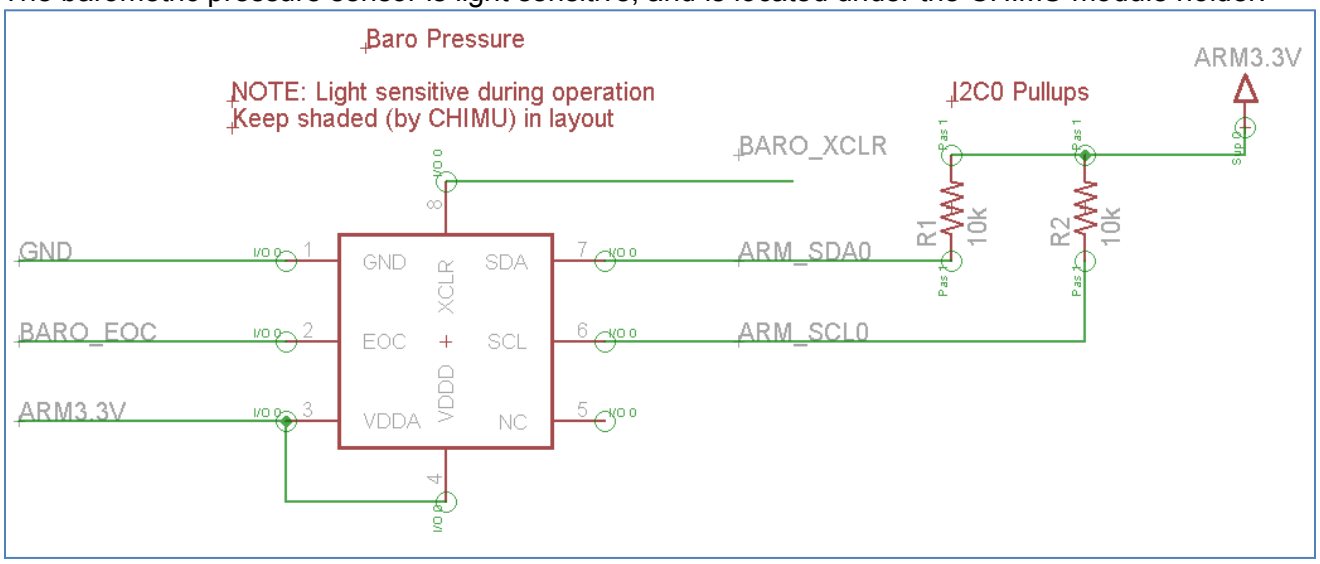
3.7 LEDs

LEDs (green, red and blue) are controlled by the ARM.



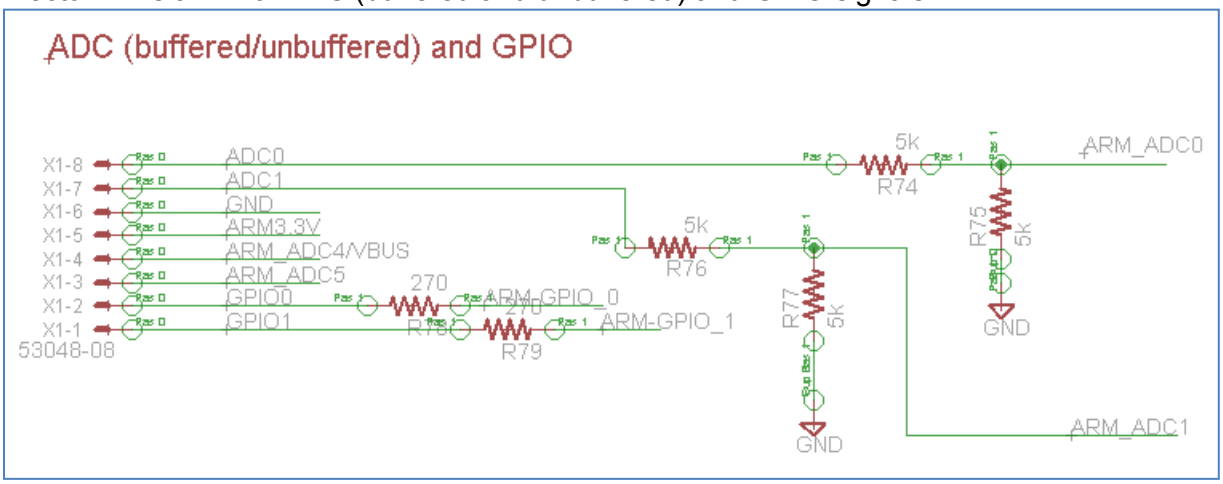
3.8 Barometric Pressure Sensor

The barometric pressure sensor is light sensitive, and is located under the CHIMU module holder.



3.9 ADC and GPIO

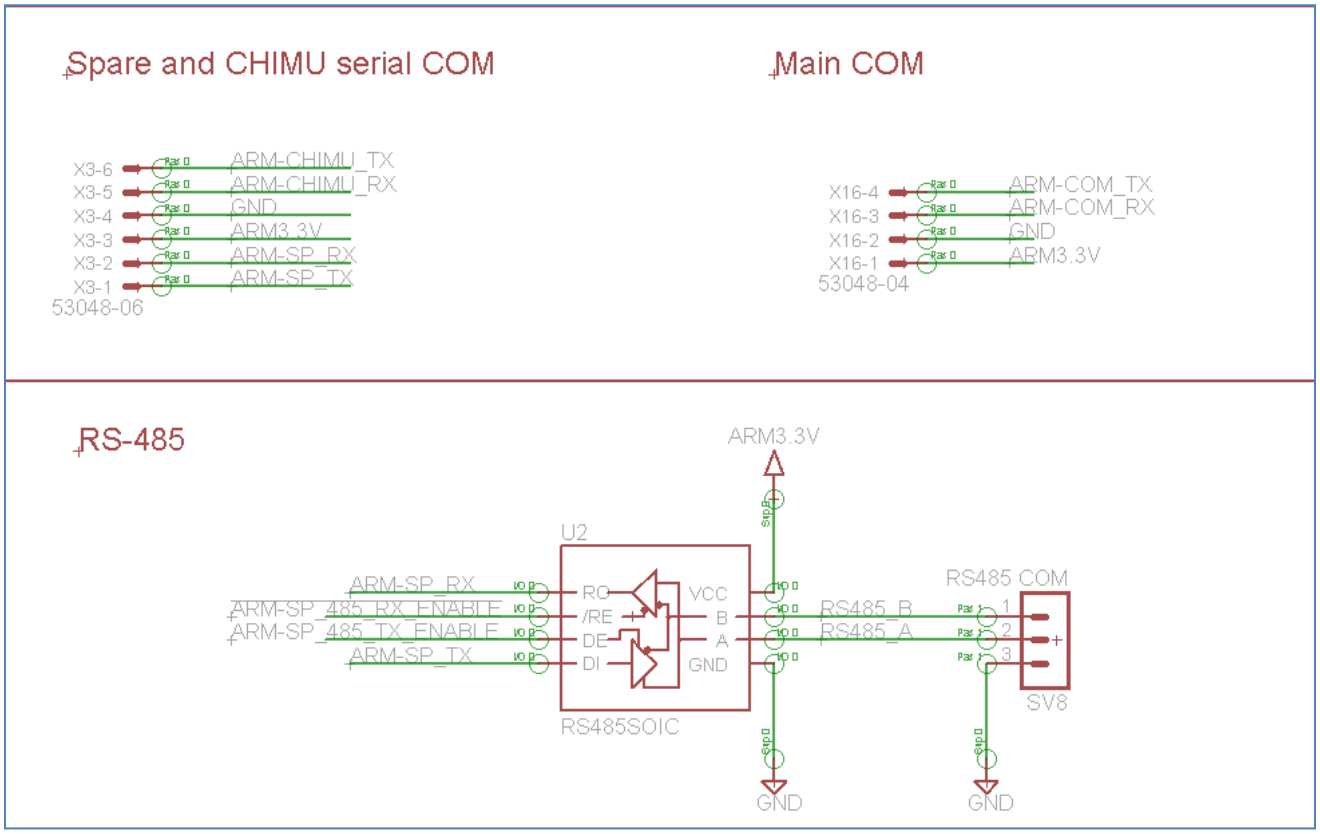
Connector X1 is a mix of ADC (buffered and unbuffered) and GPIO signals.



3.10 Communication ports

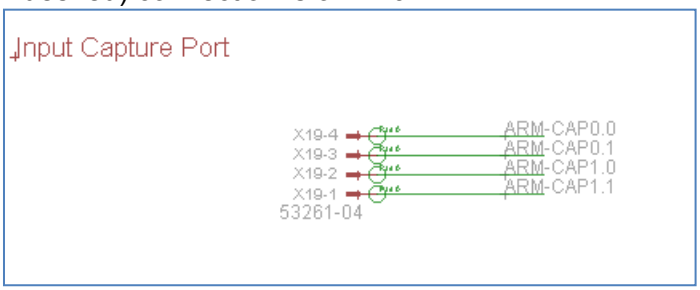
Main com is on X16. Spare com is on X3 and can be routed thru the RS-485 driver to SV8.

ARM-CHIMU serial port can be used as well if the CHIMU serial pins are disabled or if CHIMU is not present.



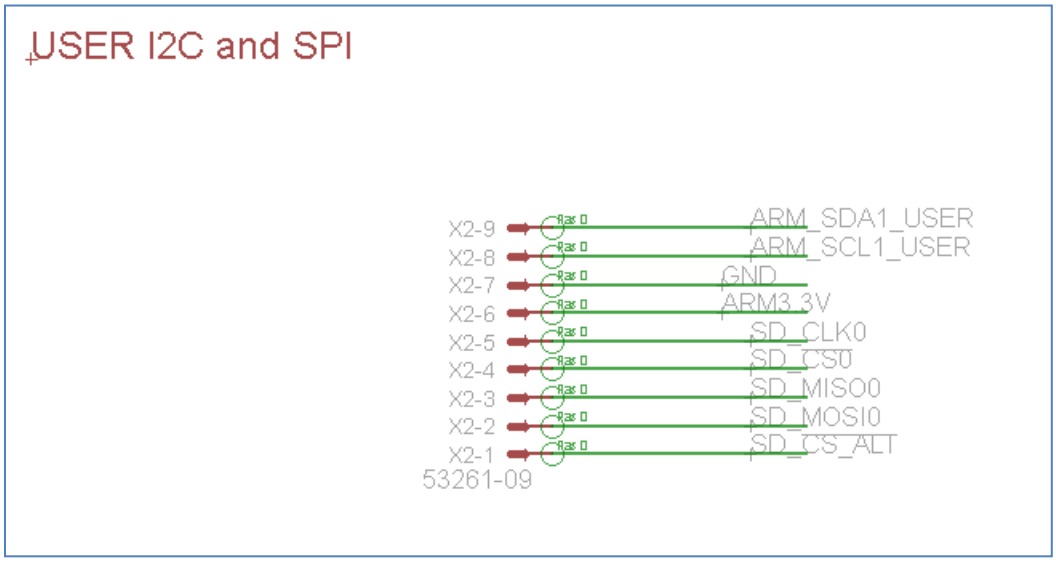
3.11 Input Capture port

Input capture (or GPIO if desired) connection is on X19.



3.12 User I2C and SPI

User I2C lines and SPI pins are located on X2. SPI pins are common with the SD card, and can be used for debugging SD operation or for an alternate SPI device if SD card is not used.



4. Hardware Integration

Presented in this section are selected hardware interface comments to help ease integration of the unit in the end user system.

Please note - the Monkey is an open electrical device with no case. It has no on board protection from short circuits or accidental electrical damage. No system is fool proof, and all correct use and planning for events in case of failure are the responsibility of the user.

Ryan Mechatronics cannot be held responsible for accidental or intentional damage caused by this unit either directly or indirectly.

4.1 Power

4.1.1 Input Power

Input power to the board is 5V but the Monkey core electronics all operate internally off of 3.3V generated via an on board low dropout linear regulator. There are three methods for powering the board. 5V input, USB (5V) input or 5V input from a servo connection (after modification to the solder jumpers that remove isolation of the servo signals, which is not recommended).

The 5V input on SV4 is common to the USB power bus. If you provide 5V power to the board, the onboard regulator will generate 3.3V output for the electronics.

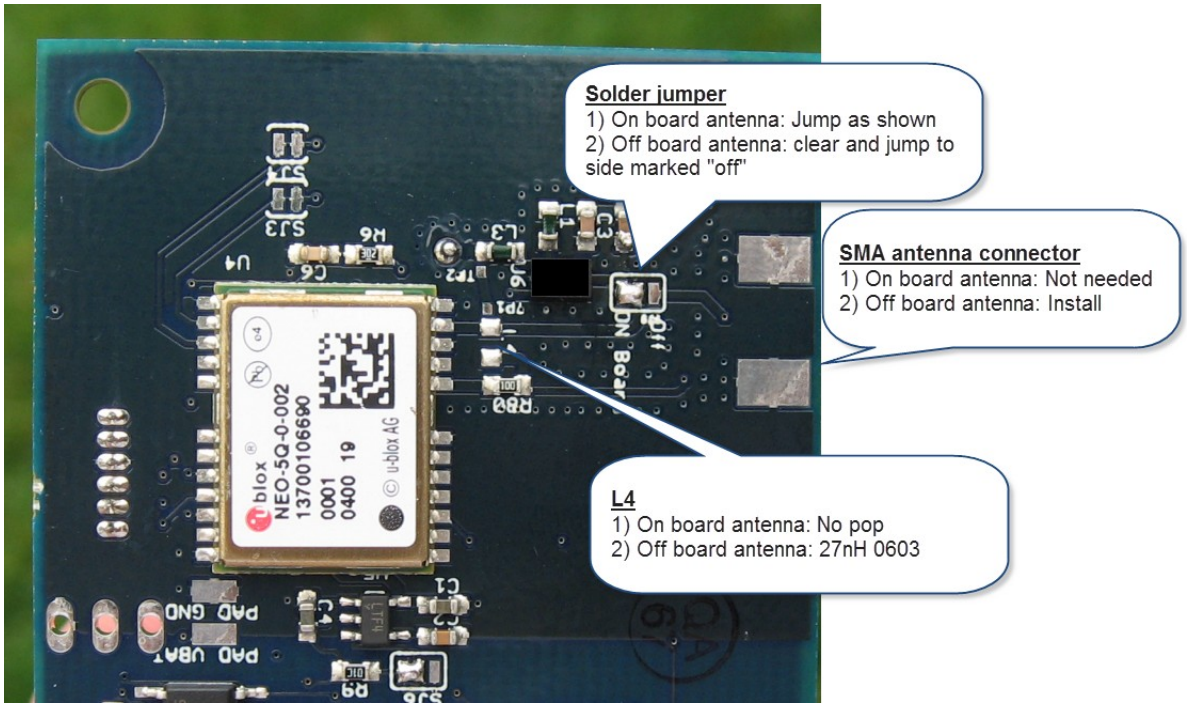
Do NOT supply more than one power supply to the unit (i.e. USB power and 5V). This will ultimately lead to damage of the Monkey or your PC.

Critical Warning: When using USB power, the bare circuit board is powered by your USB port. Shorting the unit out or overvoltaging it can directly damage your PC. Take extra precaution when using it directly interfaced to your PC.

4.2 GPS Antenna Options

The Monkey has an on board active patch antenna for GPS reception, but with a solder jumper, inductor, edge SMA connector and user supplied antenna, an external antenna to be used instead.

The graphic below shows how to enable / disable the onboard passive antenna or the external antenna. Only one or the other may be used at one time.


Solder jumper
1) On board antenna: Jump as shown
2) Off board antenna: clear and jump to side marked "off"
SMA antenna connector
1) On board antenna: Not needed
2) Off board antenna: Install
L4
1) On board antenna: No pop
2) Off board antenna: 27nH 0603

5. Software Interface

A set of core Monkey base software will soon be released as open source and can be found at www.ryanmechatronics.com. Monkey is intended for developers, so all functionality, while tested, may not be included in this source code. Any missing desired code is the responsibility of the user and not the responsibility of Ryan Mechatronics.

5.1 Recommended tools

We highly recommend using Rowley Crossworks (http://www.rowley.co.uk) Crossworks for ARM as the tool for reprogramming the Monkey. Rowley tools are very simple to use and based on the GCC compiler chain.

In addition to the Crossworks package, the CrossConnect LITE and SWD adapter should be purchased if debugging on board using the SWD connector is planned.

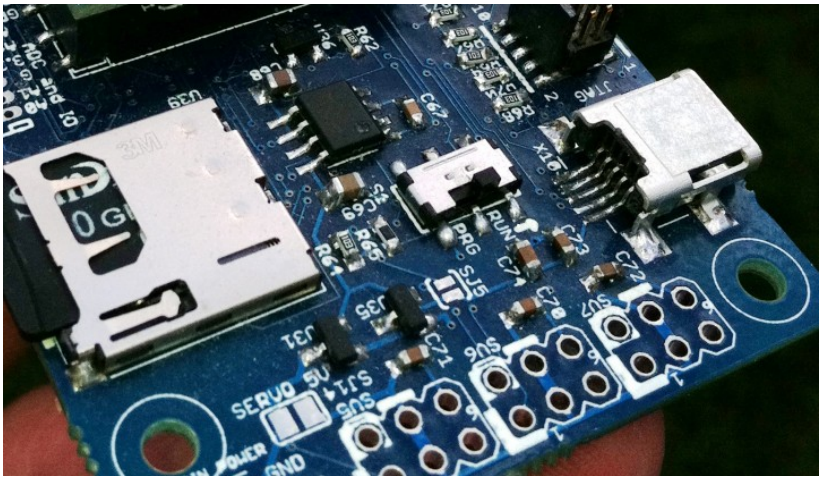
5.2 Firmware Upload Procedure

Firmware can be uploaded using the SWD connector and suitable Cortex debugging tools, or it can be uploaded via the serial port as an Intel HEX formatted file. An example of uploading firmware via this method can be found in Appendix A – Reprogramming Example.

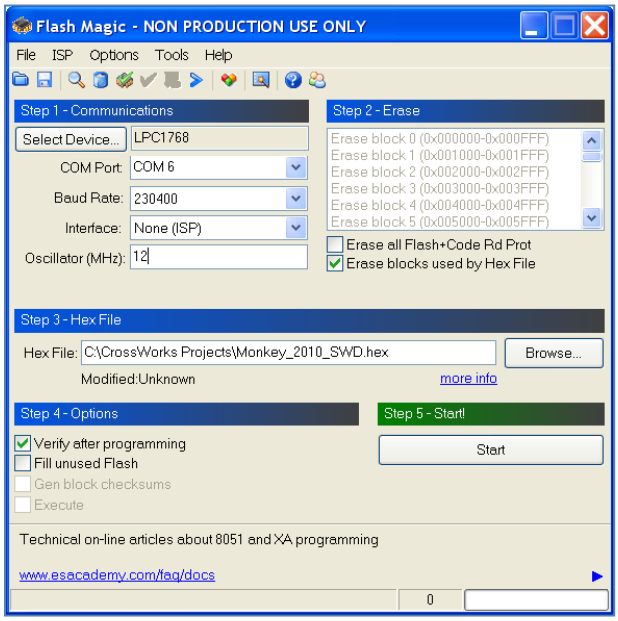
6. Appendix A – Reprogramming Example

Steps to load a new Hex file (firmware image) into the Monkey 2010 board

1) Download and install the latest version of *FlashMagic* from this site: (http://www.flashmagictool.com/)
2) Power down Monkey
3) Remove CHIMU module (if present) from Monkey board (to be on the safe side)
4) Plug USB node or other USB to serial converter into Monkey
5) Move the **S4** switch on Monkey away from **RUN** (this is a little slide switch near the USB connector)



6) Power up Monkey
7) Run *FlashMagic* and reprogram
   a. Open settings file (.fms), or if .fms file is not available, select settings shown below



   b. Change COM port to your com port

c. Change path to .hex file to where you stored the hex file to download
d. Press the “start” button, it will flash and verify
e. If it fails, try pressing the reset button on the Monkey board and try again
f. If it still fails, try powering the unit via a USB cable so grounds are common
g. If it still fails, drop the baud rate to 57600
h. If it still fails, cycle power on the Monkey and try again

8) Close *FlashMagic*
9) Power board down
10) Flip switch S4 to **RUN**
11) Put CHIMU back on (be **CAREFUL ABOUT PIN ALIGNMENT**!)
12) Power up and verify new code is running